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COUPLING LENS

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COUPLING LENS

[Kappuringu renzu]

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[There are no amendments to this patent.]

Claims

1. A coupling lens that optically couples an optical fiber, and an integrated photoelectric/electrooptical converter that is equipped with a light source at its center and on the periphery of which a photoreceiver is disposed, wherein diffraction gratings are respectively formed on both sides of one substrate, and the respective diffraction gratings are composed such that the phase difference distribution of the central part of any of these diffraction gratings corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, and the phase difference distribution of the peripheral portion that adjoins this central portion corresponds to the phase difference distribution of the peripheral portion that is distant from the optical axis in the convex lens.

2. The coupling lens described in Claim 1, wherein the above-mentioned diffraction gratings are of the blazed type.

3. A coupling lens that optically couples an optical fiber, and an integrated photoelectric/electrooptical converter that is equipped with a light source at its center and on the periphery of which a photoreceiver is disposed, wherein Fresnel lenses are respectively formed on both sides of one substrate, and the respective Fresnel lenses are composed such that the phase difference distribution of the central part of any of these Fresnel lenses corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, and the phase difference distribution of the peripheral portion that adjoins this central portion corresponds to the phase difference distribution of the peripheral portion that is distant from the optical axis in the convex lens.

4. The coupling lens described in any one of Claims 1-3, wherein a non-reflecting coating is applied to the diffraction gratings or Fresnel lenses, such that the light source or light rays from the optical fibers due not cause unnecessary reflected light to be generated by the diffraction gratings or Fresnel lenses.

#### Detailed explanation of the invention

[0001]

##### Technical field of the invention

The present invention relates to a coupling lens that is provided on the power receiving optical system of an optical feed system, etc., for coupling an optical fiber and an integrated photoelectric/electrooptical converter.

[0002]

##### Prior art

Figure 2 shows a conventional example of a transmission system wherein one optical fiber is used for the transmission path and connects two optical signal transmitters, and bidirectional communication is conducted through this optical fiber, and energy is supplied from one optical signal transmitter (this is also called the primary optical signal transmitter) to another optical signal transmitter (this is also called the secondary optical signal transmitter). A light source 110, optical branching coupler 120 and photoreceiver 130 are provided on the primary optical signal transmitter 10. The optical branching coupler 120 is composed by integrating a convex lens and a prism, and a light wavelength selection filter 122 is formed on the surface of the prism.

[0003]

A coupling lens 210 and an integrated photoelectric/electrooptical converter 220 are provided on the secondary optical signal transmitter 20, and the coupling lens 210 is composed by coaxially disposing a convex lens 211, a double-sided conical lens 212 and a spherical lens 213. In addition, the integrated photoelectric/electrooptical converter 220 is composed by respectively disposing a light source 221 in the central part thereof, and a small photoreceiver array 222 and a large photoreceiver array 223 in the area around the former. Figure 3 shows an example of the composition of the integrated photoelectric/electrooptical converter 220. The optical fiber 30 has connectors 311, 312 at both ends, and these are respectively connected to the primary optical signal transmitter 10 and the secondary optical signal transmitter 20. In addition, the emission wavelengths of the light source 110 and the light source 221 differ from one another, and the light wavelength selection filter 122 of the optical branching coupler 120 has the characteristic that the transmittance is large for the emission wavelength of the light source 110 and the reflectance is large for the emission wavelength of the light source 221.

[0004]

In a system like that described above, the optical signals and optical energy are transmitted as follows. The light emitted from the light source 110 of the primary optical signal transmitter 10 is focused by the convex surface 121 of the optical branching coupler 120, and incides on the end surface 31 of the optical fiber 30 supported by the connector 311. This light is transmitted through the optical fiber 30, and incides on the secondary optical signal transmitter 20 from the end surface 32 of the optical fiber 32 that is supported by the connector 312. In general, as shown in Figure 3(a), the far-field pattern of light transmitted through an optical fiber has an intensity distribution that is large at the center and becomes smaller at the periphery. Of the light that incides from the optical fiber 30, the central portion of the far-field pattern, where the majority of the energy thereof is contained, passes in order through the convex lens 211 and the double-sided conical lens 212 and reaches the photoreceiver 222 and the photoreceiver array 223 of the integrated photoelectric/electrooptical converter 220. Therefore, the majority of the light energy that incides from the optical fiber 30 on the secondary optical signal transmitter 20 ends up reaching the photoreceiver 222 and the photoreceiver array 223 as shown by the intensity characteristics in Figure 3(b).

[0005]

The intensity of the light emitted from the light source 110 of the primary optical signal transmitter 10 is modulated to a form that superimposes the direct current component and the alternating current component as shown in Figure 4. The direct current component accounts for

the majority of the intensity of this light, while the alternating current component constitutes the signals that are transmitted from the primary optical signal transmitter 10 to the secondary optical signal transmitter 20. The large-area photoreceiver array 223 receives the majority of the light that incides on the integrated photoelectric/electrooptical converter 220 from the optical fiber 30, and photoelectric conversion is performed and the power that serves as the source for driving the secondary optical signal transmitter 20 is supplied. Relatively speaking, the response speed of the small photoreceiver 222 is rapid compared to the large-area photoreceiver array 223, and the incident light is electrooptically converted and an electrical signal that converts the alternating current of the incident light is generated.

[0006]

On the other hand, the light emitted from the light source 221 of the secondary signal transmitter 20 passes in order through the spherical lens 2213, the double-sided conical lens 212 and the convex lens 211, and incides on the end surface 32 of the optical fiber that is supported by the connector 213, and is then transmitted through the center of the optical fiber 30 and incides on the primary signal transmitter 10 from the end surface 31 of the optical fiber that is supported by the connector. This light is reflected by the light wavelength selection filter 122 of the optical branching coupler 120, and incides on the photoreceiver 130. The intensity of this light has been modulated by the signals transmitted from the secondary signal transmitter 20 to the primary signal transmitter 10, and this is converted into an electrical signal by photoelectric conversion at the photoreceiver 130.

[0007]

Problems to be solved by the invention

In the secondary signal transmitter of an optical transmission system like that described above, the energy of the incident from the optical fiber is efficiently coupled with the photoreceiver, so it is desirable that the coupling lens is so composed that the far-field central portion among the emitted light of the optical fiber is guided to the photoreceiver located in the area around the light source. Moreover, in this instance the coupling lens must be so composed that the emission from the light source incides on the optical fiber from the portion corresponding to the far-field periphery of the emitted light of the optical fiber. Conventionally, three single lenses like those shown in Figure 2 have been employed in order to satisfy such requirements. In addition, the double-sided conical lens differs from the usual spherical lens insofar as it cannot be produced by polishing a plurality of lenses simultaneously, so there is also the problem that it is extremely expensive. Therefore, the problem of this invention is to provide a coupling lens that has few parts and that can be produced easily.

[0008]

Means to solve the problems

In the invention in Claim 1 to solve such problems, in a coupling lens that optically couples an optical fiber, and an integrated photoelectric/electrooptical converter that is equipped with a light source at its center and on the periphery of which a photoreceiver is disposed, diffraction gratings are respectively formed on both sides of one substrate, and the respective diffraction gratings are composed such that the phase difference distribution of the central part of any of these diffraction gratings corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, and the phase difference distribution of the peripheral portion that adjoins this central portion corresponds to the phase difference distribution of the peripheral portion that is distant from the optical axis in the convex lens. The above-mentioned diffraction gratings of the above-mentioned Claim 1 can be of the blazed type (the invention in Claim 2).

[0009]

In the invention in Claim 3, in a coupling lens that optically couples an optical fiber, and an integrated photoelectric/electrooptical converter that is equipped with a light source at its center and on the periphery of which a photoreceiver is disposed, Fresnel lenses are respectively formed on both sides of one substrate, and the respective Fresnel lenses are composed such that the phase difference distribution of the central part of any of these Fresnel lenses corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, and the phase difference distribution of the peripheral portion that adjoins this central portion corresponds to the phase difference distribution of the peripheral portion that is distant from the optical axis in the convex lens. In the inventions in any one of Claims 1-3, a non-reflecting coating is applied to the diffraction gratings or Fresnel lenses, such that the light source or light rays from the optical fibers do not cause unnecessary reflected light to be generated by the diffraction gratings or Fresnel lenses.

[0010]

In other words, when the coupling lens described in Claim 1 is employed, the light emitted from the light source of the integrated photoelectric/electrooptic converter incides on the central portion of the diffraction gratings formed on the surface that faces the converter of the coupling lens, and is deflected by diffraction. Since the phase difference distribution of the central portion of this diffraction grating corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, the section is annular just like a case

where the incident light to this portion incides on the concave conical lens, and as it proceeds it is deflected such that it spreads and is propagated through the inside of the coupling lens, and reaches the peripheral portion of the diffraction grating that is formed on the surface facing the optical fiber of the coupling lens. Since the phase difference distribution of the peripheral portion of these diffraction gratings corresponds to the phase difference distribution of the peripheral portion, which is distant from the optical axis in the convex lens, the incident light to this portion is deflected such that it is focused and emitted through the coupling lens, just as when the incident light to this portion incides on the convex lens, and then reaches and incides on the end surface of the optical fiber.

[0011]

In addition, the light that is emitted from the optical fiber, and that incides on the central portion of the diffraction gratings that are formed on the surface facing the optical fiber of the coupling lens, is deflected by diffraction. Since the phase difference distribution of the central portion of these diffraction gratings corresponds to the phase difference distribution of the portion around the optical axis in the concave conical lens, the section becomes annular just like a case where the incident light to this portion incides on the concave conical lens, and as it proceeds it is deflected such that it spreads and is propagated through the inside of the coupling lens, and reaches the peripheral portion of the diffraction gratings formed on the surface facing the integrated photoelectric/electrooptical converter of the coupling lens. Since the phase difference distribution of the peripheral portion of these diffraction gratings corresponds to the phase difference distribution of the peripheral portion, which is distant from the optical axis in the convex lens, the incident light to this portion is deflected such that it is focused and emitted through the coupling lens, just as when the incident light to this portion incides on the convex lens and then reaches the region where the photoreceiver of the above-mentioned converter is disposed.

[0012]

In the coupling lens in Claim 3, the phase difference distribution of the Fresnel lens surfaces formed on both sides thereof is equivalent to the diffraction gratings formed on both surfaces of the coupling lens in Claim 1, and acts similarly with respect to incidental light. Therefore, like the coupling lens in Claim 1, the coupling lens in Claim 3 optically couples the integrated photoelectric/electrooptical converter and the optical fiber. By making the above-mentioned diffraction gratings the blazed type, it is possible to raise the diffraction efficiency (the invention in Claim 2), and by applying a non-reflective coating to the diffraction

gratings or Fresnel lens surfaces it is possible to avoid unnecessary reflection (the invention in Claim 4).

[0013]

#### Mode of embodiment of the invention

Figure 1 is an explanatory diagram for describing the mode of embodiment of this invention. Figure 1(a) shows the overall composition of the secondary optical signal transmitter, while Figure 1(b) shows the specifics of the coupling lens thereof. In other words, as in Figure 2, a coupling lens 230 and an integrated photoelectric/electrooptical converter 220 are provided on the secondary optical signal transmitter shown in Figure 1(a). This coupling lens 230 forms respective diffraction gratings, and in particular blazed (saw-tooth) type diffraction gratings, on both sides of the substrate. The coupling lens 230 is composed by disposing a light source 221 in the center as shown in Figure 2, and by disposing as shown in Figure 3(b) a small photoreceiver 222 and a large photoreceiver array in the area around the former respectively. The optical fiber 30 is equipped with a connector 311 (not shown in the figure) and a connector 312 on both ends, and is connected to the primary optical signal transmitter (not shown in the figure) and the secondary optical signal transmitter respectively.

[0014]

As shown in the details of the coupling lens in Figure 1(b), a diffraction grating 231 is formed in the central part on the surface facing the optical fiber 30, and a diffraction grating 232 is formed on the peripheral part adjacent to this diffraction grating 231, respectively. In addition, a diffraction grating 233 is formed on the central part of the surface facing the integrated photoelectric/electrooptical converter 220, and a diffraction grating 234 is formed on the peripheral part adjacent to this diffraction grating 233, respectively. The diffraction grating 231 and diffraction grating 233 have phase difference distributions that respectively correspond to the portions around the optical axis on the separate concave conical lenses. In addition, the diffraction grating 231 and diffraction grating 233 have phase difference distributions that respectively correspond to the peripheral portion that is distant from the optical axis on the separate convex lenses. The surface of the conical lens to which reference is made here is not limited to conical surfaces that are accurate geometrically, and it can be further added that the surface of the convex lens is similarly not limited to a spherical surface that is geometrically accurate.



[0015]

When a coupling lens like that described above is employed, as shown by the arrow in Figure 1(a), the light emitted from the integrated photoelectric/electrooptical converter 220 incides on the diffraction grating 233, and is deflected in the same manner as when it incides on the central portion of the concave conical lens due to diffraction and the section becomes annular, and it is propagated through the inside of the coupling lens 23 such that it spreads as it proceeds, and then reaches the diffraction grating 232. Moreover, in the case of the diffraction grating 232, the light is deflected such that it is focused, as in the case where it incides on the peripheral portion of the convex lens due to diffraction, and it is then emitted through the coupling lens 230 and reaches the end surface 32 of the optical fiber, and incides on the optical fiber 30. In addition, the light that is emitted from the optical fiber 30 and that incides on the diffraction grating 231 is deflected in the same manner as the case where it incides on the central portion of the concave conical lens due to diffraction and the section becomes annular, and is propagated through the inside of the coupling lens such that it spreads as it proceeds, and then reaches the diffraction grating 234. Moreover, in the case of the diffraction grating 234, the light is deflected so that it is focused just as in the case where it incides on the peripheral portion of the convex lens due to diffraction, and it is emitted through the coupling lens 230 and ends up reaching the region that includes the photoreceiver 222 and the photoreceiver array 223 of the integrated photoelectric/electrooptical converter 220.

[0016]

When it comes to diffraction gratings like those described above, such methods as writing for example with an electron beam on a substrate to which a photoresist is applied are known (see for example Shinji Enomoto, et al., "Diffraction Efficiency of Electron Beam Lithography Micro Fresnel Lenses", Technical Report of the Institute of Electronics and Communication Engineers, OQE83-89 (1983)), and reproduction is possible by means of injection molding with the diffraction gratings produced with said method as the master.

[0017]

In the foregoing the present invention was embodied such that diffraction gratings were formed on the coupling lens, but Fresnel lens surface can also be formed on both sides of the substrate. This case is shown in Figure 1(b) with the coupling lens 240 and the Fresnel lens surfaces 241-244. Any of the shapes of the Fresnel lens surfaces are rotationally symmetric to the area around the optical axis of the coupling lens, so the Fresnel lens surfaces can be formed by cutting the surface with for example a numerically controlled precision lathe, and the coupling lens can be formed thereby. In this case as well, it goes without saying that reproduction by

injection molding is possible. It is preferable that non-reflective coating is applied beforehand so that unnecessary reflected light is not generated on the diffraction gratings or the Fresnel lens surfaces.

[0018]

#### Effects of the invention

According to this invention, the inventive coupling lens differs from a conventional coupling lens and can be manufactured as one unit, so there are the advantages that a lens holder for aligning the axes of a plurality of single lenses becomes unnecessary, and inexpensive mass production becomes possible since reproduction by injection molding, etc. is easy.

#### Brief description of the figures

Figure 1 is an explanatory diagram to explain a mode of embodiment based on this invention.

Figure 2 is a configuration diagram showing the prior art of an optical signal transmission system.

Figure 3 is an explanatory diagram of the disposition of the integrated photoreceiver of the photoelectric/electrooptical converter, and the intensity distribution of the signal light that incides on this.

Figure 4 is a waveform diagram that shows the signal light transmitted from the primary optical signal transmitter.

10	Primary optical signal transmitter
2	Secondary optical signal transmitter
30	Optical fiber
31, 32	End faces
110, 221	Light sources
120	Optical branching coupler
130, 222	Photoreceivers
210, 230, 240	Coupling lenses
211	Convex lens
212	Double-sided conical lens
213	Spherical lens
223	Photoreceiver array
231-234	Diffraction gratings
241-244	Fresnel lens surface

311, 312 Connectors

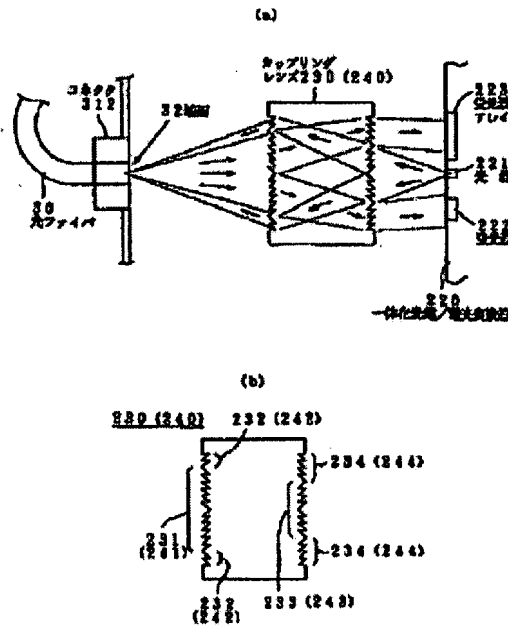


Figure 1

Key: 30                    Optical fiber  
 32                    End face  
 220                    Photoelectric/electrooptical converter  
 221                    Light source  
 222                    Photoreceiver  
 223                    Photoreceiver array  
 230 (240)            Coupling lens  
 312                    Connector

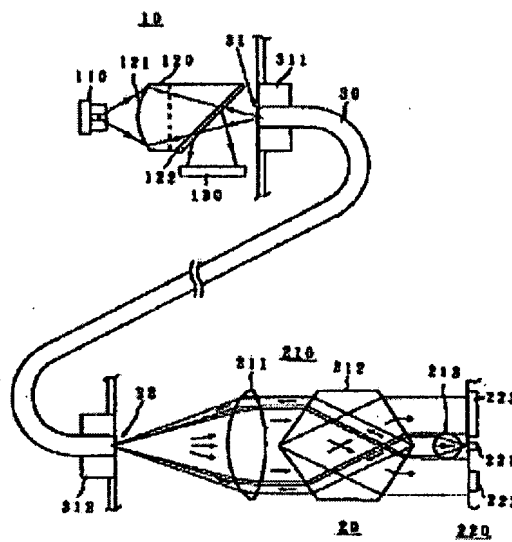


Figure 2

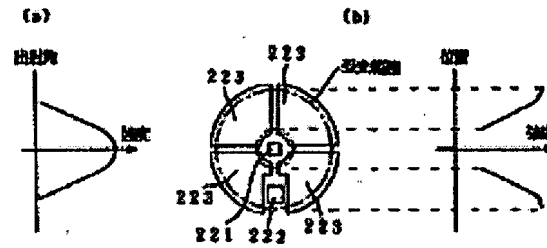


Figure 3

- Key: 1 Emission angle  
 2 Intensity  
 3 Scope of photoreception  
 4 Position  
 5 Intensity

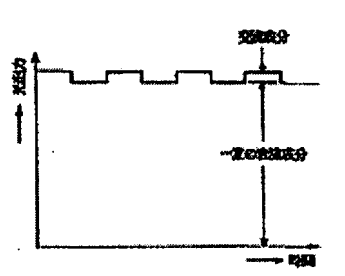


Figure 4

- Key: 1 Optical output  
 2 Alternating current portion  
 3 Fixed direct current position  
 4 Time